ILLINOIS STATE WATER SURVEY
Meteorologic Laboratory
at the
University of Illinois
Urbana, Illinois

INVESTIGATION OP THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO. MEASUREMENTS

Seventh. Quarterly Technical' Report

1 April 1963 - 30 June 1963

Sponsored by
U. S. Army Electronics Research and Development Laboratory
Fort Monmouth, New Jersey

CONTRACT NO. DA-36-039 SC-87280
DA Task 3A99-07-001-01

AD______________________Accession No.____________
Illinois state water Survey Division, urbana, Illinois. INVESTIGATION OP THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS - E. A. Mueller

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A computer program was written to determine the best estimate of rainfall rate subject to a criterion for insuring that under-estimates of large magnitude are not made.

Results of a study of evaporation effects on raindrop distributions are presented.

UNCLASSIFIED

1. Radar Meteorology
2. Drop Size Distribution
3. Coalescence Theory
4. Contract DA-36-039 SC-8728O

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INVESTIGATION OF THE QUANTITATIVE DETERMINATION OF POINT AND AREAL PRECIPITATION BY RADAR ECHO MEASUREMENTS

SEVENTH QUARTERLY TECHNICAL REPORT

1 April 1963 - 30 June 1963

Signal Corps Contract: DA-36-039 SC-87280

DA Task 3A99-07-001-01

Sponsored by

U. S. Army
Electronics Research and Development Laboratory
Fort Monmouth, New Jersey

To record and analyze data on raindrop-size distribution in various parts of the world. These data will be correlated with appropriate radar parameters in order to improve the capability of radar in measuring surface rainfall intensities for Army applications such as radioactive rainout prediction, trafficability, and communications.

Prepared by

E. A. Mueller
Project Engineer

G. E. Stout
Project Director

William C. Ackermann, Chief
Illinois State Water Survey

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PURPOSE

The object of this research is to study the utility of radar equipment in measuring surface precipitation and to improve radar techniques in measuring precipitation for application by the Army to radioactive rainout prediction, trafficability, and communications . Considerable effort is being directed toward determining the correlation between radar variables and actual rainfall quantities by means of raindrop-size distribution.

ABSTRACT

During the quarter three raindrop cameras were operated on the East Central Illinois Raingage Network. Because of drought conditions only 38 rolls of raindrop camera film were obtained. A portion of these data was edited to determine if the data were appropriate for detailed analysis.

Processing of the raindrop camera data has been continuing in a routine manner. Sixteen rolls of raindrop camera data were measured and preliminary calculations performed.

Since the original objective of this contract was to determine measuring techniques for radar measurement of rainfall, the correlation between the rainfall rate and the radar reflectivity has been re-examined, utilizing the assumption that the measurement of Z was quite accurate. Because of the change in the computer facilities in the University and the requirements of a smaller Z Increment, the program for obtaining the best estimate

of rainfall rate given a particular radar reflectivity has been rewritten for the 7090 computer. This program has not been checked as yet.

Work has been continuing on the estimation of the evaporation effect on raindrop size distributions, and a short synopsis of the findings and sample effects on drop size distributions are presented.

PUBLICATIONS, LECTURES,. REPORTS, AND CONFERENCES

On June 3, 1963, Mr. E. A. Mueller and Mr. R. G. Semonin visited Evans Laboratory at Belmar, New Jersey. Results of the contract to date were discussed as well as future plans for the data collection on this contract at Flagstaff, Arizona.

RADAR OPERATIONAL PROGRAM

CPS-9

The CPS-9 radar has performed exceptionally well during the quarter with no outages due to radar difficulties. It has been noticed that the slip rings on the radar are in poor condition, and corrective measures will have to be taken during the coming period. The upper section of the slip rings on the main slip ring assembly has become loose, and the rings are free to rotate through about 30° of antenna rotation. This places undue strain on the connecting wires, and in fact a number of these wires hav already broken. It has been possible to continue operations of the radar set by reconnecting the necessary leads to spare slip rings on the assembly. Since the RHI unit is not used on the CPS-9, there were a number of spare slip rings available. During the next quarter, the antenna will have to be dismounted, the receiver transmitter removed from the antenna assembly, the entire antenna assembly removed from the spindle, the slip ring wires reconnected, and the slip rings tightened.

TPS-10

The TPS-10 radar was put into operation in early June. The radar now is capable of photographing the RHI scope with either a 16-mm camera or a 35-mm camera or both. A number of minor problems have been corrected on the radar, and at present it is in good operating condition.

M-33

The M-33 radar on loan from the Signal Corps was received along with a gasoline generator. This radar has not been placed into operation since its condition is poor. However, another M-33 which was obtained from the National Science Foundation and found to be in better initial condition was put into service. N routine data have been collected because of a lack of means of recording the data. The radar has been used to track balloons carrying an aluminum foil target for measurements of the wind, and it seems to be very adequate for this purpose. It has also been used to obtain the vertical profile of reflectivity with time.

RAINDROP CAMERAS

The southernmost raindrop camera, which has been referred to as camera C, was Installed on May 10, 1963, and since that time has been operating satisfactorily. The only difficulty experienced with the three cameras has been the loss of one flash condenser. This condenser failed on camera B, and so one rain storm was missed because of faulty operations. The center camera, B, was removed on June 24, for refurbishing and shipment to Flagstaff, Arizona, for data collection during mid-July to mid-August. On return from Flagstaff, this camera will be reinstalled and the drop cameras will be operated during the fall season rainfall period.

There have been 38 rolls of raindrop camera data obtained to the present. These data are being reviewed to determine which storms appear the most promising for detailed analysis. It is planned that only the storms with concurrent and well-time raindrop and radar data will be analyzed in detail. In some of the cases, the rainfall appears to be widespread and without cellular structure so that there is little to be gained in detailed analysis. It has been previously noted in this type of rainfall that the variability in time at one location is not very great, and, therefore, it is not expected that the variability in space will be very large. Nevertheless, in order to confirm this conclusion, it is intended to conduct meso analyses of a few storm systems which produce continuous rainfall. On other occasions when good storms. pass over the East Central Illinois Raingage Network, the major cells, or the cells of most interest, did not pass over the raindrop cameras.

DATA ANALYSIS

Raindrop Data Reduction

A total of 16 rolls of raindrop data was measured. Nine of these rolls were obtained from Island Beach, New Jersey, and seven from Coweeta, North Carolina. These data are processed by the computer as they are measured.

During this summer's data collection at Flagstaff, Arizona, the data will be measured as soon as it is obtained and preliminary calculations performed so that the Information will be available immediately for the Evans Laboratory's use. The data will also be supplied to Alex Long and Dr. Vincent J. Schaefer for their research. Depending upon the magnitude of data obtained, either one or both projection tables will be transferred to the measurement of this data.

Effects of Evaporation on Drop Size Distributions

The study of evaporation has continued in an attempt to explain the variations in drop size distributions with varying condensation levels as previously reported. Further study of the literature relating to this subject was made. Equations for the change in drop size with height have been developed by Best[1] for two atmospheric temperature structures, in which the average relative humidity may be specified. A recent paper by Abraham[2] uses an atmosphere in which the relative humidity is allowed to vary linearly with height. He also selected a temperature profile which approximated conditions In southern Arizona for July afternoons.

Both Best's and Abraham's equations can be put into the general form

$$D_f^2 = D_i^2 - K^2 \tag{1}$$

where D_f is the final drop diameter and D_i is the original drop diameter. K^2 Is determined by the assumed atmospheric conditions and by the height from which the drop falls. K may also be seen to be the diameter of the largest drop which will be completely evaporated during the fall.

Equation (1) shows the change In the diameters of the individual drops; further corrections are necessary to maintain the ordinate of the distribution curves in terms of number per cubic meter per 0.1 mm.

Abraham's equation for the southern Arizona climate was used to illustrate an extreme case of evaporation. The assumed temperature was 35°C at the surface, with a 10°C/km lapse rate. The relative humidity was assumed to be 25 percent at the surface and varied linearly to 100 percent at the cloud base, 2 km above the surface and 3 km above mean sea level. In this case, K^2 was calculated to be 0.0133 cm^2. A coalescence curve for a = 1600 and ß = 0.5 was taken as the original distribution; the effect of evaporation is shown in Figure la. It may be observed from this figure that evaporation produces a shift in the mode to smaller diameters, a decrease in magnitude of the mode, and a broadening of the distribution. It may also be calculated that the rainfall rate and the total number of drops have been reduced.

Since the conditions of Figure la represents a very extreme case of evaporation, a curve has also been plotted for a situation approximating the Majuro conditions. The same coalescence curve was used as for the original distribution. Shown in Figure lb are the distributions resulting from falls through atmospheres 1: approximating the Majuro level 1 and level 8 conditions. (Level 4: condensation levels under 450 feet; level 8: condensation levels between 1600 and 2000 feet). The level 1 curve is practically unchanged from the original distribution. The K^2 for this case was only 0.00013 cm^2 because of the assumed 93 percent relative humidity and cloud base height of 370 feet. A greater change is noted for level 8 (relative humidity 78 percent, average height 1720 feet). The mode shifted from 1.1 mm to 1.05 mm. The rainfall rate decreased from 23.6 mm/hr to 20.1 mm/hr, and the total number of drops decreased from 1053 to 977. The distribution was also broadened slightly. K^2 for this case was 0.0022 cm^2.

It would, therefore, appear that because of the low condensation levels and high humidities at Majuro, evaporation has only a small effect on these drop size distributions, even where the condensation levels are high. Present calculations also suggest that the effects of evaporation are opposite of those needed for

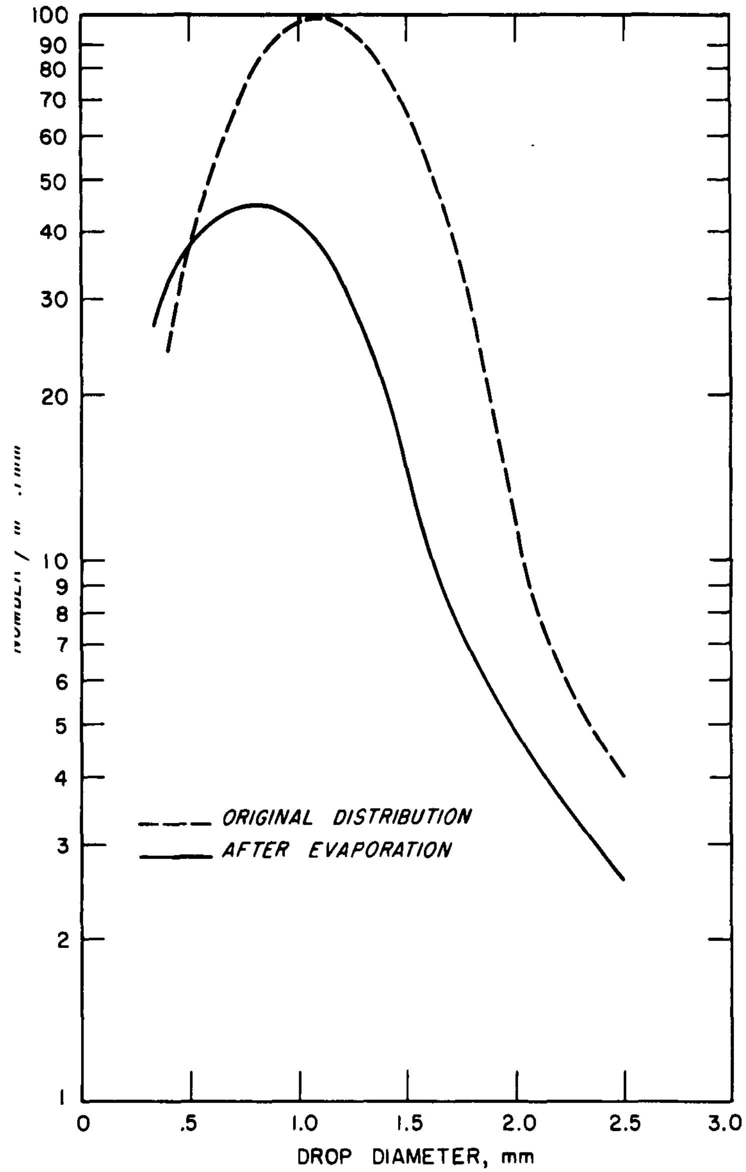

FIG. Ia. EFFECT ON A DROP SIZE DISTRIBUTION PRODUCED BY EVAPORATION DURING A 2 km FALL THROUGH A VERY HOT, DRY ATMOSPHERE.

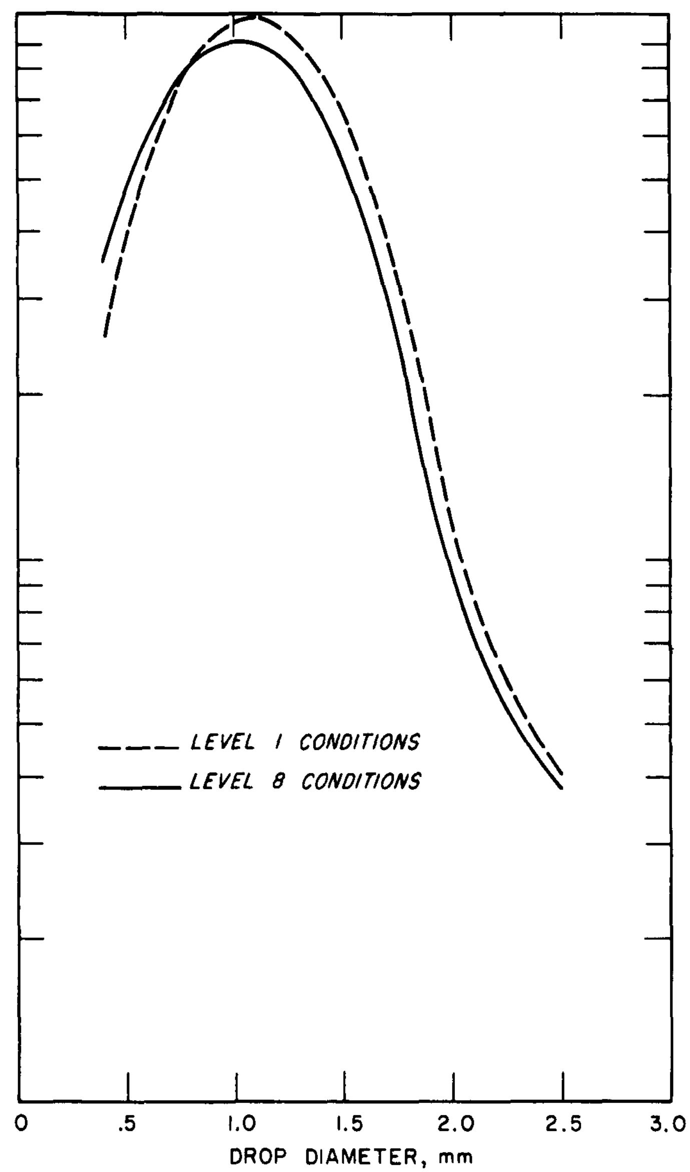

FIG. Ib. EFFECT ON A DROP SIZE DISTRIBUTION PRODUCED BY EVAPORATION DURING A FALL THROUGH TWO DIFFERENT MAJURO ATMOSPHERES.

explanation of the differences observed in the Majuro data. Further study of the low rainfall rate cases is planned. This will include allowances for the changing rainfall rate with evaporation. This study should show more definitely the magnitude and nature of evaporation effects in the situations where this effect is most noticeable.

Correlation of Rainfall Rate With Radar Reflectivity

On reviewing the status of the correlation between radar reflectivity and rainfall rate, it was decided that a new program for the 7090 Computer must be written in order to obtain the best estimate of rainfall rate, subject to a criterion for insuring that underestimates of large magnitude are not made. Under the new criterion, the independent variable Z is separated into one-decibel levels. The most appropriate rainfall estimate is determined by minimizing the function

$$\Sigma R_i \left| R_i - R^* \right|$$

where R^* is the estimate and R_i is the observation. This program has been written but has not as yet been checked.

Another program has been written and is in the process of being checked out to determine the coalescence coefficients in a less subjective manner. Work will continue on both of these programs during the next quarter.

SUMMARY AND CONCLUSIONS

Raindrop camera measurements have been proceeding satisfactorily and the work necessary for moving a raindrop camera to Flagstaff, Arizona, was initiated. Calculations from the drop size data are proceeding in a routine manner.

Two new computer programs have been written and are in the process of being checked out. During the coming quarter, these programs will be proven and some trial data run.

Calculations of evaporation effects indicate that this effect is small. Study is continuing in this area.

REFERENCES

1. Best, A. C, "The Evaporation of Raindrops", _Quart. J. R. Met. Soc._, V. 78, No. 336, 1952, pp. 200-225.
2. Abraham, Farid F., "Evaporation of Raindrops", _J. Geophys. Research_, V. 67, No. 12, 1962, pp. 4673-4682.

PERSONNEL

The following personnel were engaged in the research during the seventh quarter:

Name and Title	Starting Date	Hours Worked	Terminated
G. E. Stout Project Director	10/1/61	70	
Eugene A. Mueller Electronic Engineer	10/1/61	510	
Arthur L. Sims Research Assistant	5/13/63	290	

Name and Title	Starting Date	Hours Worked	Terminated
Alfred S. Davis Research Assistant	6/10/63	56	
Stanley G. Peery Electronics Technician II	3/1/63	510	
Victor Munson Electronics Technician I	3/11/63	510	
Andre H. Changnon Engineering Assistant	4/1/63	92	
Marian E. Adair Meteorological Aide I	9/24/62	220	
Edna M. Anderson Meteorological Aide I	10/1/61	510	
Ruth Eadie Meteorological Aide I	11/31/61	428	6/17/63
Dorothy A, Tew Meteorological Aide I	10/1/61	510	
Ileah W. Trover Meteorological Aide I	9/10/62	255	
Nazir Ansari Statistical Clerk	10/1/61	203	
Gerald W. Swanson Statistical Clerk	10/31/62	103	5/24/63
Michael K. Robinson Laboratory Assistant	5/27/63	52	
Karen Sue Adair Laboratory Helper	6/17/63	16	

Mr. Arthur L. Sims has been added to the professional staff on this contract. He received his BS degree in 1952 from Southern Illinois University, Carbondale, Illinois, and attended the Air Force program In Meteorology at UCLA. He served four years in the Air Weather Service. Between 1956 and May 1963 he was engaged as an electrical engineer for General Electric Company.

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STUDY OF MEASUREMENT OF INTENSITY OF
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